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Estimating ages by third molars: Stages of development in Brazilian young adults

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ABSTRACT

The purpose of this study was to estimate age through the analysis of third molar stages of development in Brazilian young adults. A cross-sectional study was conducted by analyzing 659 panoramic X-rays. Two techniques were used to establish the stages: Modified Scoring (MST) and Demirjian (DT). Regression formulas were calculated. Statistical analyses were conducted by *t*, Kappa tests, and simple and multiple linear regressions (5% level of significance). Out of the participants, 40.7% were female and 59.3% were male, with ages from 15–22 years. The Kappa test showed good results for intra-observer (0.84 for MST and 0.95 for DT) and inter-observer examination (0.81 for MST and 0.92 for DT). Differences were found in the stages of tooth formation between male and female, but differences were not observed between the left and right sides. We found that both DT and MST underestimated the ages in about 6 months, depending on the used classification and number of teeth. These methods are appropriate for assessing the ages of young Brazilians, although the DT showed better reproducibility.

1. Introduction

Estimating the ages of young individuals based on anatomical indicators is important for both corpse identification and establishing the age of penal responsibility. In forensic dentistry, one indicator of age is the formation of third molars, which at the age of eighteen years, are the only teeth still being formed. The development of these teeth is a long process, which may not be complete until the age of twenty-two years.[1–3]

Different techniques and methods have been proposed for the classification of different stages of tooth formation, which often involve panoramic X-ray analysis.[4–22] However, panoramic X-ray analysis must be expanded for use among different populations[23] to determine if the same techniques can be universally applied with confidence.

In this study, we conducted an analysis using the Modified Scoring Technique (MST)[4,8,17,22] and the Demirjian stage classification (DT)[6,7,9,11–16,18–22,24] in a Brazilian young adult population. Thus, we determined if it is possible to relate tooth formation with age. Differences between the sexes were also analyzed, because other studies have shown differences in the chronology of tooth formation between men and women.[2,4,7,14,15,25,26]

There are currently no studies on third molar formation of a Brazilian population using the DT or the MST. Thus, the aim of the present study was to use these two techniques to estimate the age of young adults according to third molar development. The stages of the chronology of tooth formation were also established.

2. Materials and methods

A retrospective, cross-sectional study was conducted with the analysis of 659 X-rays of both males and females aged between fifteen and twenty-two years. The X-rays were collected at a private radiology practice in the City of São Paulo, Brazil; São Paulo is the most important economic Brazilian center, with a population of 12 million of inhabitants.

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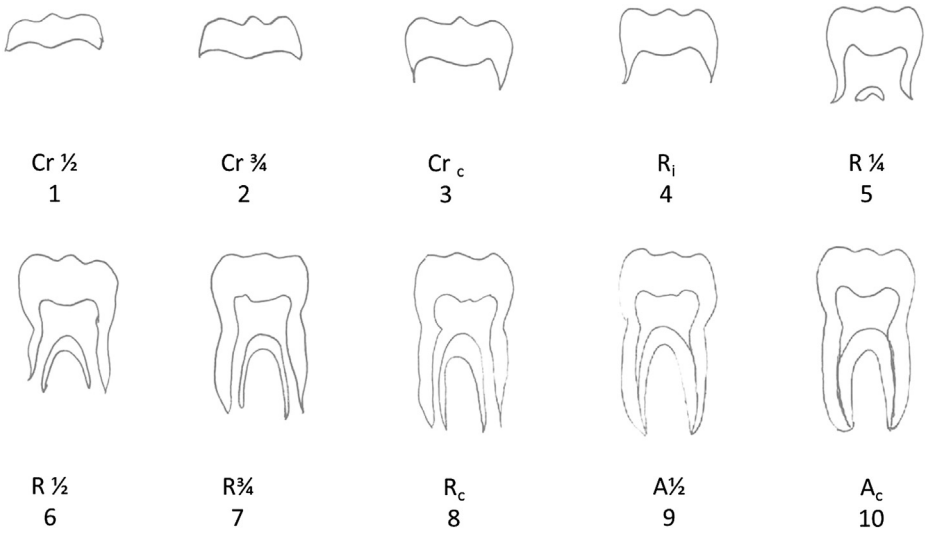

Fig. 1. Modified Scoring Technique (MST) stages of mineralization according to the modification technique of Gleiser and Hunt,[25] modified by Köhler et al.[26]

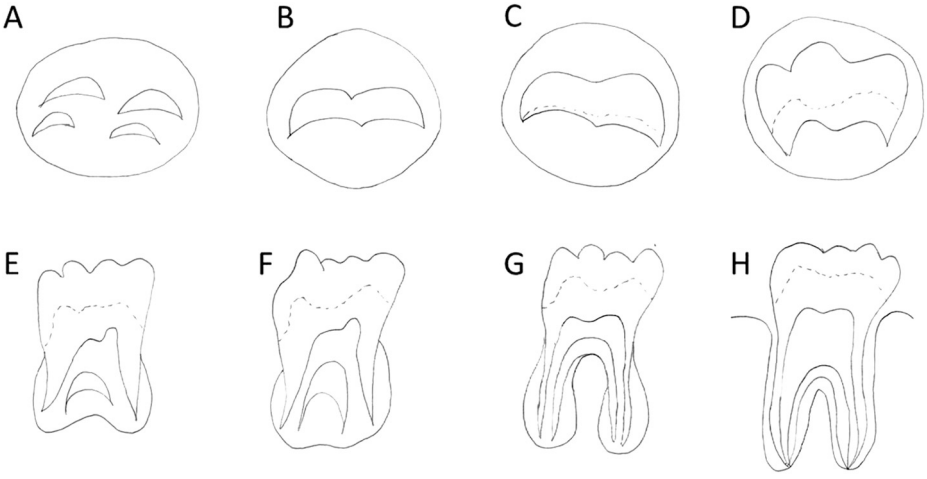

Fig. 2. Demirjian's stages of mineralization.[24]

The patients' records were from the North of the city, they had a known age, were leucoderms and, regarding the socioeconomic condition, they lived in this middle-class area of the city. We included the dental records in which there were no general health problems.

The examinations were performed during the year of 2010 and we used the MST[26] and the DT[24] to establish the stages of dental element formation. The investigator had no access to the patients' real age. Figs. 1 and 2 show the developmental phases.

The main criterion for including a panoramic X-ray in the study was the presence of at least one third molar. Exclusion criteria were a history of serious illness or abnormal dentition growth.

To make it easier to analyze the results, tooth nomenclature was assigned according to anatomic location. This nomenclature designated "UR" as the upper right third molar, "UL" as the upper left third molar, "LL" as the lower left third molar and "LR" as the lower right third molar.

For the classification of the MST[4,8,17,21] each stage of tooth formation was given a specific point count, on a scale from one to ten, following the classification from A to J, respectively.[4] The MST is a stage classification which was originally proposed by Gleiser and Hunt[25] and was modified by Köhler et al.[26] Stage A indicated that the crown was in the middle of its formation (C½), stage B indicated that the crown formation was almost complete, up to three-quarters formed ($C^3/_4$), and stage C indicated that the crown was completely formed (C c). The first stage in which root formation was observed was stage D (R i), followed by stage E, where there was evidence of the root dividing into two or three, with the root being one quarter formed (R ¼). Stage F indicated that the root was half its final size, and the separation of the roots had become more evident (R ½). In stage G, the root was almost complete and had

Table 1
Number of X-rays by sex and age.

	Gender		
	Female	Male	Total
15–16	38	34	72
16–17	43	38	81
17–18	42	41	83
18–19	48	44	92
19–20	52	41	93
20–21	60	32	92
21–22	52	21	73
22–23	44	29	73
Total	379	280	659

Table 2
Kappa statistics for reproducibility (inter- and intra-observer) for the Modified Scoring Technique (MST) and the Demirjian Technique (DT).

Technique	Category	Kappa	SE[a]	*p*
MST	Inter	0.81	0.05	<0.05
	Intra	0.84	0.04	<0.05
DT	Inter	0.92	0.02	<0.05
	Intra	0.95	0.02	<0.05

[a] SE = Standard error.

reached three quarters of its final size (R $^{3}/_{4}$), while stage H corresponded to a completely formed root. The last two stages refer to the closure of the apex, with phase I indicating that this process had initiated (A ½) and stage J indicating that the apex had closed (A c). In this latter stage, the tooth had erupted.[2,27]

According to the DT,[6,7,9,11–16,18–22] there are eight different stages of tooth formation, which are letter-graded from A to H. In stage A, the upper protuberances have been mineralized but have not yet fused, which occurs when the tooth is at Stage B (when the definitive crown morphology has been established). In stage C, the crown is half-formed. The pulp is visible, and the deposit of dentine is occurring. In stage D, the formation of the crown is complete as far as the amelodentinary junction and the pulp is trapezoidal in shape. In stage E, root division occurs, and the length of the root is less than the length of the crown. In stage F, the length of the root is the same as the length of the crown, and the roots narrow at the apices. In stage G, the root walls are parallel and the root apex is still open. Finally, in stage H the root apices are completely closed.

The analyzed teeth were classified using the described techniques by two examiners. To check the intra-examiner validity, 10% of the X-rays were re-analyzed by each examiner, using each technique.

When there was difficulty in distinguishing between two adjacent stages, the pictures were analyzed using Adobe® Photoshop®

Table 3
Frequency of stages of tooth formation, by sex and probability for tooth at each stage, according to the Modified Scoring Technique (MST).

	N	Median	SD	Min.	25%	50%	75%	Max.	N	Median	SD	Min.	25%	50%	75%	Max.
	Female UR[a]								Male UR[a]							
A	0	0.0	0.00	0.0	0.0	0.0	0.0	0.0	0	0.0	0.00	0.0	0.0	0.0	0.0	0.0
B	0	0.0	0.00	0.0	0.0	0.0	0.0	0.0	2	16.5	0.56	16.1	16.1	16.5	16.9	16.9
C	5	18.4	3.30	15.1	15.5	18.2	20.4	22.9	2	18.1	2.61	16.3	16.3	18.1	20.0	20.0
D	14	17.0	1.76	15.1	15.7	16.5	17.6	21.2	20	17.2	1.71	15.2	16.1	16.9	18.6	21.3
E	39	18.3	2.11	15.1	16.2	18.3	20.1	22.1	23	17.6	2.23	15.0	15.5	18.0	19.2	22.7
F	37	18.5	2.04	15.3	16.9	18.2	19.9	22.5	22	17.9	2.24	15.1	15.9	17.6	19.7	22.1
G	53	18.7	2.19	15.11	16.9	19.1	20.4	22.4	43	18.3	2.10	15.0	16.8	18.9	19.8	22.6
H	78	19.2	2.16	15.1	17.4	19.1	21.1	22.8	47	19.1	2.24	15.1	17.2	19.1	20.7	22.5
I	36	19.9	2.03	15.1	18.6	20.6	21.2	22.8	33	19.0	2.13	15.1	17.2	19.1	20.7	22.5
J	51	20.1	2.08	15.3	18.7	20.5	21.8	22.9	47	19.3	2.23	15.6	17.3	19.8	21.6	22.9
	Female UL[b]								Male UL[b]							
A	0	0.0	0.00	0.0	0.0	0.0	0.0	0.0	0	0.0	0.00	0.0	0.0	0.0	0.0	0.0
B	2	18.6	4.94	15.1	15.1	18.6	22.1	21.1	1	18.7	0.00	18.7	18.7	18.7	18.7	18.7
C	6	19.3	1.41	16.6	19.0	19.6	22.3	22.4	8	16.7	1.52	15.2	15.6	16.2	17.7	19.5
D	26	18.0	2.45	15.1	15.8	17.1	19.9	22.9	17	18.2	2.08	15.1	16.9	18.0	19.9	22.4
E	38	18.4	2.07	15.1	16.1	18.4	20.1	22.1	18	17.1	2.10	15.1	16.9	18.0	19.9	22.4
F	29	18.6	2.21	15.3	17.1	18.3	20.1	22.7	21	17.7	2.09	15.1	15.7	17.6	19.4	21.9
G	61	18.5	2.03	15.1	16.7	18.4	20.3	22.8	39	18.1	2.15	15.0	16.2	17.9	19.8	21.7
H	77	19.4	2.22	15.1	17.8	19.5	21.2	22.9	59	19.2	2.06	15.3	17.6	18.9	21.1	22.9
I	50	20.1	1.60	17.1	19.0	20.3	21.3	22.8	42	18.8	2.10	15.1	17.3	18.8	20.2	22.3
J	46	19.9	2.32	15.1	18.4	20.6	21.9	22.9	42	19.7	2.07	15.6	18.1	19.9	21.6	22.8
	Female LL[c]								Male LL[c]							
A	0	0.0	0.00	0.0	0.0	0.0	0.0	0.0	0	0.0	0.00	0.0	0.0	0.0	0.0	0.0
B	2	15.7	0.07	15.7	15.7	15.7	15.8	15.8	0	0.0	0.00	0.0	0.0	0.0	0.0	0.0
C	14	17.6	2.19	15.1	15.5	17.5	19.3	21.2	9	16.5	1.15	15.2	15.5	16.3	17.2	18.4
D	23	18.2	1.81	15.1	16.4	18.8	19.7	21.1	15	17.7	1.90	15.0	16.1	18.0	18.9	21.9
E	50	18.1	2.17	15.1	16.4	17.7	19.8	22.9	25	17.2	1.61	15.0	18.8	16.9	18.3	20.5
F	29	18.5	1.92	15.5	16.6	18.3	19.9	22.1	23	17.3	1.95	15.1	15.7	16.9	19.0	22.4
G	37	18.5	2.33	15.0	15.8	18.9	20.2	22.8	26	17.7	1.48	15.1	16.5	17.6	18.9	21.1
H	68	19.7	1.96	15.1	18.4	20.2	21.2	22.8	55	19.2	2.16	15.1	17.6	18.5	21.3	22.7
I	71	19.8	2.08	15.1	18.4	20.2	21.2	22.9	65	19.4	2.06	15.0	18.1	19.7	20.7	22.9
J	20	20.4	2.31	15.5	18.2	21.2	22.2	22.7	18	19.9	1.91	16.0	19.0	19.8	21.4	22.8
	Female LR[d]								Male LR[d]							
A	0	0.0	0.00	0.0	0.0	0.0	0.0	0.0	0	0.0	0.00	0.0	0.0	0.0	0.0	0.0
B	3	15.5	0.35	15.1	15.1	15.5	15.8	15.8	2	15.2	0.00	15.2	15.2	15.2	15.2	15.2
C	13	17.6	2.23	15.1	17.7	17.1	19.3	22.1	3	16.8	1.34	15.9	15.9	16.3	18.4	18.4
D	24	18.5	2.23	15.2	16.5	18.5	20.6	22.1	12	17.6	1.96	15.5	16.5	17.3	18.5	20.3
E	44	17.9	2.19	15.1	16.1	17.2	19.7	22.5	32	17.1	1.84	15.0	15.7	16.8	18.6	21.9
F	38	18.4	2.13	15.3	16.6	18.1	20.1	22.9	20	17.3	1.72	15.1	16.1	16.9	18.9	20.3
G	46	19.1	2.08	15.1	17.4	19.2	20.4	22.9	25	18.6	1.97	15.1	17.6	18.1	19.5	22.7
H	68	19.6	2.13	15.0	18.4	19.9	21.3	22.8	53	18.7	1.99	15.0	17.3	18.3	20.2	22.7
I	57	19.7	2.18	15.1	18.1	20.4	21.2	22.9	65	19.4	1.97	15.3	18.1	19.5	20.9	22.9
J	23	20.1	2.16	15.7	18.1	20.7	22.1	22.7	25	20.1	2.38	15.1	19.0	20.9	22.1	22.9

[a] UR = Upper right third molar.
[b] UL = Upper left third molar.
[c] LL = Lower left third molar.
[d] LR = Lower right third molar.

(Adobe Systems Incorporated, San José, CA),[4,17] which allowed small and delicate features, such as the junction between the enamel and the dental cement, to be seen. Furthermore, the comparison of the third molar with the preceding second molar could be performed.[4]

Based on these data, tables were organized to relate the age of the individuals concerned, which was known, to the stages of third-molar formation as observed.

Statistical analyses were conducted by the statistical program STATA 10.0 (StataCorp 4905 Lakeway Drive, College Station, TX 77845 USA), using *t*-tests, Kappa tests, and simple and multiple linear regression. The level of significance was set at 5%.

This research project was approved by the Research Ethics Commission at the School of Dentistry of the University of São Paulo (FOUSP) as administrative procedure No. 17/2010.

3. Results

Of the total participants, 40.7% were female and 59.3% were male. The minimum age was 15 years and the maximum was 22 years (mean, 18.89 years). Table 1 shows the distribution of the X-rays analyzed by sex and known age. We analyzed 2332 teeth in 659 individuals. The Kappa test showed good results both for intra-observer examinations (0.84 for MST and 0.95 for DT) and for inter-observer examination (0.81 for MST and 0.92 for DT). The test results for the DT higher level of agreement than those for the MST (Table 2).

Table 3shows the stages of formation of each tooth as analyzed according to the MST classification, while Table 4 shows the same stages observed according to the DT. The tables also show the probability of the occurrence of each stage. Fifty percent (50%) of the sample presented the stage E in the MST classification of the upper teeth and had around 18 years, both male and female (Table 3); similarly, in DT, the E stage appeared on 50% of the 18 years females on the same teeth (Table 4).

In most cases, differences were observed between male and female subjects when calculating the average age for each stage of dental formation, according to each of the classifications used. However, no significant differences were found in the stages of dental formation between the right-hand and left-hand sides of the sample. In addition, both classifications showed similar results (Table 5). Table 5 shows that if a person present a 3rd molar at E stage or higher at MST classification, it is probably that this individual be 18 years or older; the same can be observed with regard with the D or higher stage at DT.

Table 6 also shows the regression formulas created for the two classifications, thus allowing us to obtain the age estimates for young Brazilians. Furthermore, it can be seen that these formulas underestimate real ages in about 6 months.

Table 4
Frequency of stages of tooth formation, by sex and probability for tooth at each stage, according to the Demirjian Technique (DT).

	N	Median	SD	Min.	25%	50%	75%	Max.	N	Median	SD	Min.	25%	50%	75%	Max.
	Female UR[a]								Male UR[a]							
A	0	0.0	0.00	0.0	0.0	0.0	0.0	0.0	0	0.0	0.00	0.0	0.0	0.0	0.0	0.0
B	0	0.0	0.00	0.0	0.0	0.0	0.0	0.0	1	16.1	0.00	16.2	16.2	16.2	16.2	16.2
C	1	18.2	0.00	18.2	18.2	18.2	18.2	18.2	0	0.0	0.00	0.0	0.0	0.0	0.0	0.0
D	16	17.4	2.30	15.1	15.5	16.6	19.5	21.4	18	17.1	1.58	15.1	16.1	16.7	18.3	20.5
E	31	18.4	2.05	15.1	16.6	18.7	19.7	22.9	13	17.9	2.55	15.0	16.0	18.0	19.2	22.1
F	17	18.6	2.15	15.1	16.7	18.3	20.6	22.5	58	18.1	2.10	15.0	16.1	18.2	19.2	22.7
G	64	19.1	2.19	15.1	17.7	19.1	20.9	22.9	51	18.5	2.20	15.0	16.8	18.5	19.9	22.8
H	126	19.6	2.18	15.1	18.1	20.0	21.6	22.9	99	19.2	2.19	15.1	17.5	19.1	21.3	22.9
	Female UL[b]								Male UL[b]							
A	0	0.0	0.00	0.0	0.0	0.0	0.0	0.0	0	0.0	0.00	0.0	0.0	0.0	0.0	0.0
B	0	0.0	0.00	0.0	0.0	0.0	0.0	0.0	1	16.1	0.00	16.1	16.1	16.1	16.1	16.1
C	2	21.0	1.48	20.0	20.0	21.1	22.1	22.1	1	16.1	0.00	16.1	16.1	16.1	16.1	16.1
D	29	18.3	2.61	15.1	15.7	18.0	20.8	22.9	15	17.0	1.30	15.1	15.9	17.0	18.3	18.9
E	22	18.2	1.88	15.1	16.4	18.4	19.5	22.4	20	17.8	2.62	15.0	15.7	16.7	20.1	22.4
F	75	18.6	2.09	15.3	16.6	18.3	20.2	22.8	48	18.0	1.99	15.0	16.1	17.8	19.3	22.7
G	84	19.0	2.18	15.1	17.1	18.9	20.7	22.9	61	18.7	2.08	15.0	17.1	18.9	20.1	22.8
H	122	19.8	2.10	15.1	18.3	20.1	21.7	22.9	101	19.2	2.18	15.1	17.4	19.1	21.1	22.9
	Female LL[c]								Male LL[c]							
A	0	0.0	0.00	0.0	0.0	0.0	0.0	0.0	0	0.0	0.00	0.0	0.0	0.0	0.0	0.0
B	1	15.7	0.00	15.7	15.7	15.7	15.7	15.7	0	0.0	0.00	0.0	0.0	0.0	0.0	0.0
C	9	16.5	1.95	15.1	15.5	15.5	16.7	21.1	5	15.6	0.47	15.2	15.2	15.5	15.9	16.3
D	31	18.2	1.78	15.1	16.4	18.8	19.8	21.2	18	17.4	1.22	15.1	16.8	17.5	18.3	20.0
E	38	18.1	2.03	15.1	16.1	17.9	19.7	22.5	26	17.3	2.16	15.0	15.7	16.6	19.1	22.4
F	55	18.5	2.21	15.1	16.5	18.3	20.4	22.9	33	17.4	1.76	15.1	16.1	16.9	19.0	22.2
G	78	19.5	2.28	15.0	18.3	20.1	21.0	22.8	65	18.7	1.98	15.1	17.6	18.3	19.9	22.7
H	103	19.8	2.07	15.1	18.2	20.0	21.6	22.9	89	19.5	2.08	15.0	18.1	19.7	21.1	22.9
	Female LR[d]								Male LR[d]							
A	0	0.0	0.00	0.0	0.0	0.0	0.0	0.0	0	0.0	0.00	0.0	0.0	0.0	0.0	0.0
B	0	0.0	0.00	0.0	0.0	0.0	0.0	0.0	0	0.0	0.00	0.0	0.0	0.0	0.0	0.0
C	9	16.8	2.37	15.1	15.5	15.7	16.6	22.1	5	16.9	2.92	15.2	15.2	15.9	16.3	22.1
D	31	18.4	2.14	15.1	16.4	18.8	20.4	22.1	8	17.6	1.51	15.5	16.3	17.6	18.6	20.0
E	47	18.1	2.17	15.1	16.1	17.6	19.7	22.5	36	17.1	1.75	15.0	15.7	16.9	18.4	21.9
F	54	18.7	2.22	15.1	16.9	18.7	20.1	22.9	32	17.8	2.06	15.1	16.1	17.4	19.5	22.7
G	78	19.4	2.19	15.0	18.3	19.8	21.1	22.8	61	18.5	1.90	15.1	17.3	18.1	19.9	22.7
H	98	19.7	2.12	15.1	18.1	20.2	21.6	22.9	94	19.5	2.12	15.0	18.1	19.5	21.4	22.9

[a] UR = Upper right third molar.
[b] UL = Upper left third molar.
[c] LL = Lower left third molar.
[d] LR = Lower right third molar.

Table 5
Mean age by dental development stage, according to the Modified Scoring Technique (MST) and the Demirjian Technique (DT).

	Female		Male		p(S)[a]	Female		Male		p(S)[a]	p(ML)[b]	p(HL)[c]
	M	SD	M	SD		M	SD	M	SD			
Modified Scoring Technique												
	D18					D28						
E	18.3	2.11	17.6	2.23	<0.05	18.4	2.07	17.1	2.10	<0.05	NS	NS
F	18.5	2.04	17.9	2.24	<0.05	18.6	2.21	17.7	2.09	<0.05	NS	NS
G	18.7	2.19	18.3	2.10	<0.05	18.5	2.03	18.1	2.15	<0.05	NS	NS
H	19.2	2.16	19.1	2.24	NS	19.4	2.22	19.2	2.06	NS	NS	NS
I	19.9	2.03	19.0	2.13	<0.05	20.1	1.60	18.8	2.10	<0.05	NS	<0.05
J	20.1	2.08	19.3	2.23	<0.05	19.9	2.32	19.7	2.07	<0.05	NS	NS
	D38					D48						
E	18.1	2.17	17.2	1.61	<0.05	17.9	2.19	17.1	1.84	<0.05	NS	NS
F	18.5	1.92	17.3	1.95	<0.05	18.4	2.13	17.3	1.72	<0.05	NS	NS
G	18.5	2.33	17.7	1.48	<0.05	19.1	2.08	18.6	1.97	<0.05	<0.05	<0.05
H	19.7	1.96	19.2	2.16	<0.05	19.6	2.13	18.7	1.99	<0.05	NS	NS
I	19.8	2.08	19.4	2.06	<0.05	19.7	2.18	19.4	1.97	<0.05	NS	NS
J	20.4	2.31	19.9	1.91	<0.05	20.1	2.16	20.1	2.38	NS	NS	NS
Demirjian Technique												
	D18					D28						
D	17.4	2.30	17.1	1.58	<0.05	18.3	2.61	17.0	1.30	<0.05	<0.05	NS
E	18.4	2.05	17.9	2.55	<0.05	18.2	1.88	17.8	2.62	<0.05	NS	NS
F	18.6	2.15	18.1	2.10	<0.05	18.6	2.09	18.0	1.99	<0.05	NS	NS
G	19.1	2.19	18.5	2.20	<0.05	19.0	2.18	18.7	2.08	<0.05	NS	NS
H	19.6	2.18	19.2	2.19	<0.05	19.8	2.10	19.2	2.18	<0.05	NS	NS
	D38					D48						
D	18.2	1.78	17.4	1.22	<0.05	18.4	2.14	17.6	1.51	<0.05	NS	NS
E	18.1	2.03	17.3	2.16	<0.05	18.1	2.17	17.1	1.75	<0.05	NS	NS
F	18.5	2.21	17.4	1.76	<0.05	18.7	2.22	17.8	2.06	<0.05	NS	NS
G	19.5	2.28	18.7	1.98	<0.05	19.4	2.19	18.5	1.90	<0.05	NS	NS
H	19.8	2.07	19.5	2.08	<0.05	19.7	2.12	19.5	2.12	<0.05	NS	NS

NS = Not significant.
[a] p(S) = Statistical differences between the sexes.
[b] p(ML) = Difference between right and left sides for male participants.
[c] p(HL) = Difference between right and left sides for female participants.

4. Discussion

Using third molars as developmental markers are necessary, considering the absence of alternative methods in order to perform young adult age estimations.[14] These teeth are variable in size, formation chronology and eruption.[29,30] The common inclination of the developing third molar and also the shorter and more divergent roots make it difficult to assess their stages of development. Impacted third molars seem to differ from non-impacted third molars with regards to their root formation speeds[26,31,32]; a third molar retention had shown a delay on its development,[29–31] although other study has no found differences.[13]

When necessary, the X-rays were analyzed using Adobe Photoshop, which allowed for a more uniform appraisal.[17] Training with radiographs[33] and the use of two examiners[14] reduced bias in this study.[34]

The differences between the sexes have been analyzed previously, and other studies found differences in the chronology of dental formation between male and female subjects.[2,4,7,14,15,27,28] In our study, such differences were found at almost all stages of tooth formation, with more advanced estimated ages reported for female patients. Many studies found that third molars mature earlier in males than females,[2,16,22,27] although another study found no differences.[21] More studies are necessary to clarify this point.

Several authors have reported that there are no differences in stages of development regarding the right and left sides of the face,[15,19,22] and our study agrees with this. However, other authors have recommended evaluating both sides, to account for differences.[14,16]

As reported in other investigations,[21] we found that the DT yielded more reproducible results than the MST. An explanation could be that DT scores are based on definitive anatomical shape rather than a subjective measurement of length (half root length).[21]

Although most methods for estimating dental age are developed in population samples, these studies may be unable to detect geographical and ethnic differences in the development of dental elements.[3,4,14,22,23] As we could only assess leucoderms, this limitation was also found in our research, but we have broadened the knowledge base by reporting data on the Brazilian population.

It has been recommended the use of specific population standards in order to improve the accuracy of age estimates.[35] Olze et al.[35] compared population samples from German, Japan and South Africa using orthopantomograms; third molars mineralization status was assessed as per Demirjian's stages. The authors found that the Japanese sample was 1–2 years older than the German one, and that the South Africans subjects were 1–2 years older than the Germans. The creation of databases that include different populations may improve the confidence of age estimation measures, as required for legal implications.[16] We found that both DT and MST underestimated the ages in about 6 months, depending on the used classification and number of teeth.

Furthermore, socioeconomic conditions seem not to influence tooth development.[36,37] According to a Peruvian study that compared children of low and high socioeconomic conditions,[36] tooth growth wasn't affected by the socioeconomic condition. This finding was also observed among Portuguese skeletons, in which socioeconomic differences were more pronounced in skeletal than in dental growth. More studies are necessary to clarify this topic, since another study found that socioeconomic conditions may also influence tooth development.[14]

Current recommendations (Study Group on Forensic Age Diagnostics[38] and Forensic Anthropology Society of Europe[39]) on Forensic Age Diagnostics in living adolescents and young adults[37,38]

Table 6
Multiple regression formula for age estimation of Brazilian young adults and differences with regard to real age.

Sex	Multiple regression formula – Modified Scoring Technique	SEE[a]	DIFF[b]	SD[c]
Female	Age = 16.04 + (D18 × 0.40)	2.12	−0.59	2.46
	Age = 16.81 + (D28 × 0.32)	2.14	−0.20	2.24
	Age = 16.13 + (D38 × 0.41)	2.09	−0.56	2.41
	Age = 16.31 + (D48 × 0.38)	2.15	−0.56	2.38
	Age = 15.84 + (D18 × 0.20) + (D28 × 0.23)	2.11	−0.53	2.37
	Age = 15.81 + (D38 × 0.23) + (D48 × 0.23)	2.09	−0.59	2.41
	Age = 15.05 + (D18 × 0.26) + (D28 × −0.04) + (D38 × 0.06) + (D48 × 0.26)	2.05	−0.83	2.62
	Age = (16.04 + (D18 × 0.40)) + (16.81 + (D28 × 0.32)) + (Age = 16.13 + (D38 × 0.41)) + (16.31 + (D48 × 0.38))/4	–	−0.47	2.26
Male	Age = 15.05 + (D18 × 0.35)	2.13	−0.56	2.51
	Age = 15.91 + (D28 × 0.36)	2.10	−1.27	2.29
	Age = 14.88 + (D38 × 0.50)	1.94	−0.84	2.49
	Age = 14.55 + (D48 × 0.53)	1.97	−0.59	2.48
	Age = 15.87 + (D18 × 0.18) + (D28 × 0.17)	2.13	−0.58	2.39
	Age = 14.40 + (D18 × 0.05) + (D28 × 0.50)	1.92	−0.73	2.54
	Age = 14.71 + (D18 × 0.03) + (D28 × −0.13) + (D38 × 0.04) + (D48 × 0.58)	1.98	−1.86	2.48
	Age = (15.05 + (D18 × 0.35)) + (15.91 + (D28 × 0.36)) + (14.88 + (D38 × 0.50)) + (14.55 + (D48 × 0.53))/4	–	−0.81	2.32
Gender	Multiple regression formula – Demirjian Technique	SEE[a]	DIFF[b]	SD[c]
Female	Age = 15.91 + (D18 × 0.46)	2.16	−0.65	2.50
	Age = 16.55 + (D28 × 0.38)	2.17	−0.34	2.30
	Age = 15.54 + (D38 × 0.53)	2.09	−0.65	2.53
	Age = 15.90 + (D48 × 0.48)	2.17	−0.72	2.46
	Age = 15.53 + (D18 × 0.01) + (D28 × 0.49)	2.13	−0.49	2.28
	Age = 15.17 + (D38 × 0.41) + (D48 × 0.18)	2.11	−0.75	2.48
	Age = 14.60 + (D18 × 0.05) + (D28 × 0.08) + (D38 × 0.44) + (D48 × 0.08)	2.08	−0.67	2.55
	Age = (15.91 + (D18 × 0.46)) + (16.55 + (D28 × 0.38)) + (15.54 + (D38 × 0.53)) + (15.90 + (D48 × 0.48))	–	−0.59	2.31
Male	Age = 15.06 + (D18 × 0.51)	2.14	−0.59	2.50
	Age = 14.86 + (D28 × 0.55)	2.10	−0.45	2.47
	Age = 14.05 + (D38 × 0.66)	1.96	−0.85	2.20
	Age = 13.92 + (D48 × 0.69)	2.01	−0.77	2.64
	Age = 14.72 + (D18 × −0.31) + (D28 × 0.87)	2.12	−0.47	2.66
	Age = 13.18 + (D18 × 0.07) + (D28 × 0.70)	1.95	−1.61	2.76
	Age = 14.21 + (D18 × −0.78) + (D28 × 0.39) + (D38 × 0.23) + (D48 × 0.80)	1.97	−0.76	3.02
	Age = (15.06 + (D18 × 0.51)) + (14.86 + (D28 × 0.55)) + (14.05 + (D38 × 0.66)) + (13.92 + (D48 × 0.69))	–	−0.66	2.43

D18 = Development score for tooth 18.
D28 = Development score for tooth 28.
D38 = Development score for tooth 38.
D48 = Development score for tooth 48.
[a] SEE = Standard error of estimate.
[b] DIFF = Media of the difference between estimated age and real age (estimated age − real age) in months.
[c] SD = Standard deviation of the difference (DIFF).

provide for a combination of methods including physical examination, dental examination and radiological examination of the hand and, if required, the clavicles. In order to establish completion of the 18th year of life, in particular, a radiological examination of clavicular ossification is essential.[40,41]

Our study performed only the teeth examinations, in order to discuss the importance of improving each one of them, considering that the X-rays were taken for treatment purposes; more studies should be performed comparing the responsiveness of each method in different populations. "…sometimes the best methods are not those with the best published standard error, but those which have been tested by many on different and numerous populations, which are suitable for a specific forensic scenario, practical, user-friendly, relatively quick and cheap."[39]

5. Conclusion

We conclude that the methods used for age estimates are appropriate for assessing the age of young Brazilians and that the Demirjian method was more reproducible. In addition, we found differences of age estimates between the two sexes as reported previously.

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Author declaration
We wish to confirm that there are no known conflicts of interest associated with this publication and there has been no significant financial support for this work that could have influenced its outcome. We confirm that the manuscript has been read and approved by all named authors and that there are no other persons who satisfied the criteria for authorship but are not listed. We further confirm that the order of authors listed in the manuscript has been approved by all of us. We confirm that we have given due

consideration to the protection of intellectual property associated with this work and that there are no impediments to publication, including the timing of publication, with respect to intellectual property. In so doing we confirm that we have followed the regulations of our institutions concerning intellectual property. We further confirm that any aspect of the work covered in this manuscript that has involved either experimental animals or human patients has been conducted with the ethical approval of all relevant bodies and that such approvals are acknowledged within the manuscript. We understand that the Corresponding Author is the sole contact for the Editorial process (including Editorial Manager and direct communications with the office). She is responsible for communicating with the other authors about progress, submissions of revisions and final approval of proofs. We confirm that we have provided a current, correct email address which is accessible by the Corresponding Author and which has been configured to accept email from biazevic@usp.br.

Conflict of interest

The authors declared there is no conflict of interest.

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